SCIENCE

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PHYSICS AND DAILY LIFE[1]

THE school system of Germany has often been held up to the teachers of this country as a model of perfection. Germany has been called a nation of schoolmasters, and the wonderful progress of its industries has been attributed in no small measure to the rigid training and high efficiency of its gymnasia, its universities and its vocational schools. Even at the present moment our country is being urged on many sides to establish alongside the regular public secondary schools an independent system of vocational schools, the chief argument in favor of this plan being the fact that it was "made in Germany."

Notwithstanding the fact that the reputation of the German schools is so brilliant on this side of the Atlantic, there are many thoughtful and earnest dwellers in the Fatherland who consider the training given by their schools to be of very doubtful educational value. Thus, some twenty years ago Emperor William II. called a congress of the leading schoolmen of Germany to consider what could be done to bridge the chasm that yawned so wide and deep between the work of the schools and the daily lives of the pupils. Little was accomplished as the result of this congress. The schoolmen declared it were little short of sacrilege to experiment with schools, which had always enjoyed a reputation for perfection equaled only by that of the medieval monks. Since that time, the vocational and industrial schools of Germany have developed alongside and, in large

[1] Presented at the conference of the University of Illinois with the secondary schools of the state, November 22, 1912.

measure, independent of the "regular" schools. This unfortunate double system of public schools was made necessary because of two relentless and irreconcilable facts: namely, (1) the needs of the people; and (2) the "conservatism" of the schoolmen.

In spite of the fact that the vocational schools of Germany did bring education and life nearer together for the working classes, the children of the intellectual classes continued their double existence in the world and in the school respectively until very recently. Day has, however, now begun to dawn on the academic landscape, and efforts, which originated among the teachers of science, are now being made to establish some semblance of a relationship between the school routine and the daily lives of the pupils. The evils that are being eliminated are over-systematization, rigid uniformity and the belief that words, signs and symbols can be made to serve in the educational process in place of concrete materials and real problems.[2]

Many will doubtless recognize the similarity between the experiences of Germany and those through which this country is now passing in the matter of bringing school and life to have something in common besides the children themselves. The needs of the masses for vocational schools are only equaled by the needs of the pupils in the regular schools for mental pabulum that nourishes them and helps develop their characters. Can you doubt this in the face of trustworthy reports, like that of the City Club of Chicago, which show that the present public school system fails to reach more than half of the school population? If so, study the statistics of elimination and retardation and be impressed by the enormous annual waste in material resources thus caused—the much more impressive and disastrous waste in human resources can never be calculated.

In this state of Illinois, as you all know, the crisis is imminent. The state legislature is considering a bill for the authorization of a second independent system of schools, intended in some measure to atone for the shortcomings of the present public schools. The chief argument in favor of the proposed plan is that the schoolmen who are now in control are both incompetent and unwilling to reorganize their work so as to meet the needs of that half of the school population which is not benefited in any marked degree by the present system. In support of their argument, Germany is held before us as a model, and we are urged that, as it is in the Fatherland, so must it be here. In other words, the incompetency of the teachers in permitting the proven inefficiency of the schools to continue is condoned, and we are invited to authorize additional expenditures on the ground that others, not schoolmen, can succeed where we have failed.

What would a captain of industry think of an analogous proposition with regard to his manufacturing plant? Suppose that a plant and its employees wasted half of the raw material supplied to it; would the manager enlarge the plant and take on more hands of a different sort in an endeavor to reclaim some part of the original waste? Yet the idea is abroad that this sort of a procedure, obviously absurd in an industrial enterprise, is, nevertheless, justified in school practise. The basis for this idea seems to be the fact that teachers are supposed to be so conservative that they are unwilling even to consider a new idea, much less to adopt it.

We teachers, naturally enough, repudi-

[2] Ostwald, "Wider das Schulelend," Leipzig, 1909; Gutzmer, "Die Tätigheit der Unterrichtskommission der Gesellschaft deutscher Naturforscher und Aerzte," Leipzig, 1908.

ate this accusation. We pride ourselves on being the most progressive of all people. Do we not all use our last bit of strength to keep up to date? Yet, where there is so much smoke, there must be some fire. It behooves us then not merely flatly to deny the charge, but rather to analyze carefully our methods and results in the effort frankly to discover wherein we have given ground for popular misconceptions.

This analysis might be found to be a difficult, not to say embarrassing, undertaking if it were not that the problem may be stated in a somewhat different way which permits of a ready answer. Instead of asking what grounds we have given for a reputation of ultra-conservatism, we may ask whether we have as yet succeeded in bringing the school work close to the lives of the pupils. After graduation our education and our lives are most inextricably entangled. Is it so before graduation? For if it is, the problem of vocational education vanishes. If the life of the child is his education, or if his education is his real life, he is developing to serve society to the full extent of his abilities. But if this is not true, if his schooling and his life are to him two strangely incompatible forms of existence, then there is something radically wrong with the school. Are we then making education and life a unified existence for the pupils?

The answer to this question must be an unequivocal *No*. The simple fact that this conference and other similar conferences all over the country are considering how to bring schoolwork close to child life is complete proof of the correctness of this answer. We teachers stand convicted by our own acts. We recognize that we fail at this vital point.

But even though we fail, are we willing and ready to improve and constantly to work for a closer union of education and life? Here the answer is equivocal: some are, and some are not. Some are willing to try, but are placed in circumstances where they are not free to make the effort. They are blocked by the authority that works from above downward—particularly the latter. Others express in words their willingness to make the trial, but continue in deeds to run along in the same old rut. Still others are eager to break away from the present system and to strive for a more efficient one, but they do not know where to begin. In the hope of helping such as these in gaining a vantage-ground from which to work for the union of education and life, the following hints are given. They constitute a brief summary of the main points of agreement among those who have in some measure succeeded in breaking loose from tradition and from the vested interests of school paraphernalia and equipment.

The first of the false gods that holds and will forever hold education and life asunder is the idol of uniformity. How this graven image ever came to be given an honorable place in the temple of learning passeth all human understanding. The genius of a man, the characteristics that mark him off from his fellow men and give him his priceless personality, are his individual differences. It is because he has traits and combinations of traits which are different from those of any other man that he is interesting and powerful or weak, as the case may be. In life, it is his individual differences that mark him for success or failure, but in school these must be ignored and blighted. "Every one is best trained for his greatest usefulness in life by destroying his individual differences, by putting him through the same intellectual mill with every one else"; so says the idol of uniformity.

The absurdity of this idea in general needs not to be expanded here. It has

been recognized, and efforts have been made to suppress it as far as programs of study go. Thus there are the classical courses, the scientific courses, the technical courses, each of which is supposed to minister to a definite type of mind. But here again the idol has but been broken into smaller pieces, each fashioned after the form of the whole. This arrangement has again proven unsatisfactory, and the elective system has done much to shatter it. A perfectly rigid course is found at present only in highly specialized professional schools.

But the idol of uniformity still persists in the specifications of each single course. It is manifestly so great an administrative convenience to have a unit of physics mean the same thing—at least superficially—whether the work is done in Florida or in Oregon. So the idol has been shattered into still smaller fragments and each of these, fashioned in the likeness of the original, sits enthroned in some class-room. In this diminutive, unobtrusive, almost unnoticed form, the idol still holds sway over the greater part of the work of the schools. We have become so used to him that we do not recognize the fact that he sits between us and our goal, and effectively prevents our bringing about the long-sought union between education and life.

Is it any less absurd to suppose that every class in physics can be taught successfully in one set way, than it is to imagine that every mind can be trained successfully by the same grind or every malady cured by the same treatment? The experiences in the lives of the children of New York City and of those in Urbana are very different. Can one and the same physics be doled out to both with any hope of bringing physics close to the daily lives of both? Certainly not; any more than you can grow oranges and bananas at the North Pole. Then why do teachers usually take great pride in the nearness with which their course coincides with the standardized forms set up by social convention in defiance of the natural processes of the youthful mind? Were it not far better to take pride in the close adaptation of a course to the needs of the environment in which it is given? Hence the first essential for bringing physics close to the daily life is that the teachers free themselves from the servitude of this idol of uniformity. We must become iconoclasts long enough to smash these diminutive images into fragments.

The *credo* of the idol of uniformity is the syllabus. Strange as it may seem, there are numerous syllabi, all claiming to be authentic. When not enforced by some *pontifex maximus* of the idol of uniformity, these syllabi are fairly harmless. Their chief danger lies in the fact that they tend to focus the attention of teachers on subject matter. In this the syllabus is a just possession of the idol of uniformity, since the latter is only an image, possessing, it is true, the form of a man, but devoid of life, of soul, of spirit. Therefore following the precepts of a syllabus gives a merely superficial uniformity—it creates an external resemblance among physics courses, but does not necessarily assure them an inner similarity, a spirit of investigation, clear judgment, scientific imagination, or unity. In the matter of bringing education close to life, syllabi are as useless as the idol that inspired them.

Once we have freed our minds from the obsession of the idol of uniformity, we are ready to advance to the organization of a course of study that will have some chance of bringing physics and the daily life of the pupils who are to pursue it into close union. It is, however, useless to make outlines until we are well rid of the idol. Assuming that this has been accomplished,

there is one characteristic of the course which is of the most fundamental importance for the purpose in hand, and this is what may be called the philosophy of the course. This determines the point of view or general attitude toward the subject and also settles the method of presentation. Taken as a whole, the philosophy determines the value of the course as a contribution to the mental development of the pupils. If this philosophy is of the right sort, the choice of subject matter is of secondary importance; for then physics enters into the pupil's life as an integral part and creates an attitude toward science and an ability to solve problems scientifically. This attitude and this ability once secured, the pupil will be able to read and experiment intelligently for himself and so to extend his knowledge of the subject as occasion may require. We will try to define this philosophy in such a way that teachers may be helped in discriminating between a weak course and one likely to be of great strength in uniting education with life.

The idea that there is such a thing as the philosophy of a course of study is probably new to most schoolmen, because syllabi and college entrance requirements have so accustomed us to look only at the external form or index of subject matter as defining the excellence of a course that we have failed to notice its far more important internal organization. For the sake of making clear what is meant by the philosophy of a course, and in the hope of attracting your attention to this most fundamentally weighty problem, three types of philosophy of physics courses will be briefly outlined.

The first is the old stand-by which was expressed in the college-entrance statement that physics should teach the "laws and principles of elementary physics." With this end in view, the topics demanded by the college syllabus were sorted out under the heads Mechanics, Heat, Sound, Light and Electricity. The topics that fell under each head were then arranged in what adult teachers considered their order of simplicity. Thus in mechanics, the order was: Centimeter, Gram, Second. These were duly defined without giving the pupil any clue as to what he was to do with them. These simple elements were then compounded in various ways into meters, square centimeters, centimeters per second, grams per cubic centimeter, and so on. The distinction between mass and weight was always carefully made, and each item was carefully memorized so as to be available at the next examination.

In electricity, in like manner, we must begin with the electric charge obtained by rubbing a glass rod with the skin of an unfortunate cat—obscure and pitiful victim of science! Then followed the action of two charges on each other, with descriptions of the various stunts which the two charges could be made to perform—how they could be imprisoned and released, multiplied, divided or annihilated, as the case might be. In all of this the topics were merely described and experiments presented which might serve to illustrate them and make them concrete.

This organization of the course is generally called the "logical" order because it proceeds from what is to the adult physicist simple to what is to him complex. The philosophy back of it may be called the encyclopedic philosophy. In this type of instruction there is usually little unity, no repetition and no problems that are real to the pupils. The victims usually gained from it a hodge-podge of jumbled memories, a few catch phrases which they could not use rationally, and no ability in solving scientifically the real problems of their daily lives.

This method of teaching was dominant in physics courses from about 1890 to 1905. During this period physics justly became one of the most unpopular subjects in the high-school curriculum. Since 1905 its influence has rapidly declined for two reasons: namely, first, it overreached itself by so increasing the number of topics included in the course that it became impossible for the pupils to make even a faint pretense of memorizing them all; and second, the physics teachers themselves came to realize its inadequacy and arose in revolt and overthrew it.

The chief reasons for its inadequacy were these: (1) It gave no unity to the course, since it failed to group the topics about the great principles of physics but contented itself with the superficial classification of subjects under the heads mechanics, heat, and so on. On this account, it gave little chance for the repetition which is so necessary for the successful mastery of a subject. It also furnished little perspective among the large range of topics treated. Artesian wells seemed to the learner as important as the principle of action and reaction. (2) It took slight account of the daily lives of the pupils. Physics was a "disciplinary" subject, forsooth, like mathematics and Latin, and the more distasteful it was to the pupils the greater the benefit derived from it. (3) It conceived the mission of physics to be didactic—to teach the pupils the last word on each topic—rather than to help them to solve problems of their own making. Principles and facts were merely stated, explained, illustrated with strange experiments, and applied to utterly abstract problems like finding the number of dynes that would give a mass of ten grams an acceleration of ten centimeters per second. On this account it failed to appeal to the pupils, so that they were not motivated to act on their own initiatives.

Fortunately for the children, this encyclopedic philosophy has been, as stated, rapidly declining in influence since about 1905. There are at present two other philosophies, very different from each other, which are striving to replace it. The physics teacher must choose between these two, since he can not adopt both. The first of these is not so very different from the older one. Its motto may be expressed in the words: "The first course should give the pupils a general survey of the whole field of physics." In accordance with this motto, it advocates including in the first course something of everything, thereby retaining the old fallacy of too many topics. It, however, seeks to unify the topics by stringing them on the large theories and hypotheses of physics. Thus, the pressure of gases, evaporation, expansion by heat and electrolysis are not isolated phenomena, but are nothing but the results which the normal actions of molecules and atoms would, of course, produce. The phenomena of light do not consist of the familiar facts of vision, but are evidently and simply the effects which any one would expect electromagnetic undulations in an imponderable luminiferous ether to produce. The pupils need not learn clearly and definitely what light actually does in their daily lives, but rather must master the mechanisms which genial physicists have constructed to aid them in picturing how these effects might be brought about.

In this method the daily lives of the pupils plays a relatively subordinate part. Familiar experiences are introduced after the clever mechanisms of the wily physicists have been duly set forth. For example, all matter consists of molecules in motion. When a dish of water stands on the table, the molecules of water under the surface are more crowded together than those above the surface. At the surface

water molecules are flying off into the air and back from the air into the water. But under these conditions more molecules fly from water into air than the reverse; hence the water gradually disappears from the dish. Heat is nothing but molecular kinetic energy. If the water is heated, evidently the kinetic energy of the water molecules is increased. They therefore disappear into the air more rapidly than before, and the dish dries up more quickly. If a bell jar be placed over the dish of water, the molecules of water can not spread over the entire room, but are constrained to butt their heads against the jar. We should expect these impacts to produce a pressure on the inner walls of the jar. After a time a condition is reached in which just as many molecules fly from the water into the air as fly from the air into the water. Then evaporation should cease. We find that it does so. Under these conditions the water vapor in the jar is said to be saturated.

This second method of teaching thus seeks to interpret phenomena to beginners not in terms of immediate concepts like wet, dry, pounds, inches, pressure and the like, but in terms of less immediate abstract concepts like molecules, atom, imponderable ether, and so on. Here, again, the effort is made to impress on the pupils conceptions and interpretations which may be wholly concrete to specialists in physics, but which are totally abstract to beginners, especially those of school age. For this reason this type may be called the theoretical or abstract method.

It will be noted that this theoretical or abstract method has much in common with the encyclopedic philosophy, especially as regards method of presenting topics. It is of necessity didactic in spirit, since it proposes to impose on the pupils, not the laws and principles of physics, but a survey of the whole field, consisting in the last analysis of the theories and working hypotheses of physics. It, therefore, does not encourage originality, initiative and creative imagination, since the system which it seeks to implant has already been worked out by the masters and is so comprehensive that the pupils have to be crowded in order to cover it all in the allotted time. The pupils are thus very apt to pick up the terminology of the system long before the terms stand for anything really concrete to them and they use this terminology freely to cover up their real ignorance of how best to control the forces of nature under a given set of real conditions.

In the courses of this type you will seldom find a topic introduced by a daily experience or by a problem that arises from daily experience. These, to the pupils real and concrete things, are usually placed last under the head of applications. You will often find in these courses topics introduced by laboratory or lecture experiments; but most of these are, for beginners, little less abstract than the dynes, atoms and unit poles into which they are deftly resolved by the teacher. A thing is not concrete to a pupil merely because it is made of matter; it is concrete only when it easily associates itself with the concepts and ideas already present in his mind as the result of his previous experiences.

The abstract philosophy has developed courses that are better organized than the older courses, in that they possess greater unity. They suffer, nevertheless, from many of the faults of the former because they overemphasize the value of physical theory to beginners, and so seek to impose a ready-made system on the pupils without justifying this procedure in advance. Whatever advantages this method may be supposed to have in preparing pupils for later work in some colleges and technical

schools, the over-emphasis of physical theory carries with it an under-emphasis of the daily experiences, and this renders courses of this type little adapted to bringing physics close to daily life. Those who adopt this philosophy may not expect to contribute much to the solution of the problem before us. Their work but adds weight to the demands of that vast majority of our people who must earn their livelihood by controlling the forces of their physical surroundings and solving life's practical problems in the most scientific way.

The other philosophy which is now contending with the abstract for a controlling voice in the organization of physics courses for beginners is quite different from that just discussed. This third system places neither the laws and principles of physics, nor yet the theories and hypotheses of the science at the center of its system. Instead of these human interpretations of phenomena, it centers its ideas about the development to the utmost of the powers and latent abilities of that hope of the future of our nation, the human child himself. It holds that physics does not exist in the schools for the purpose of familiarizing young people with either the laws or the theories of physics; but rather for the sake of helping the pupils to increase their powers of controlling their physical environment intelligently and solving their life's problems rationally. If this help is wisely given, they will, of course, learn the most fundamental facts and generalizations of physics; and they will learn them not as theoretical mechanisms which may help them to imagine how phenomena might be "explained," but as practical knowledge which will help them to control the forces of nature in daily life. Because of the nature of its central idea, this type may be called the practical or concrete philosophy.

This concrete philosophy demands a very different method of treatment from that developed by the other two. The most important differences consist in introducing each topic by means of daily experiences of the pupils of each class, in discussing these topics at the outset by the methods of reasoning with which the pupils are already familiar, in working in both class room and laboratory with materials and apparatus which are in common use outside of physics classes, and in leading to conclusions which are expressed in concrete terms, like pounds and feet, rather than in abstract terms, like atoms and ether.

This method thus takes the child as he is, and seeks to enlarge his fund of information concerning what the things about him will actually do, and to increase his powers of controlling his physical surroundings. Signs and symbols are not introduced until a need for them has arisen and the ideas for which they stand have become fairly concrete by wide association with previous concrete ideas. Theories are not expounded until the pupils have acquired a broad and definite knowledge of the facts and laws which the theories are invented to explain.

The concrete philosophy thus demands an arrangement which begins where that required by the others ends, namely, with the daily life; and ends where the others would begin, with the laws and theories of physics. It lays great weight on having the pupils at the beginning of their course work much with familiar things in ways familiar to them, and insists on their solving many problems of their own making by experiments with apparatus and machines of the sort used in the world's work. It seeks to lead the pupils gradually from the crude intellectual manners with which they come to the physics classes to the more refined and rigorous methods of think-

ing with which they should leave them, at the same time gradually increasing their fund of concrete, definite, dependable and useful information.

This method makes it possible to master fewer principles in a given time; but, as the psychologists have conclusively proved, assures the pupils of a much greater chance of retaining both the subject matter studied and the methods of reasoning used as real helps in solving the real problems of later life. In other words, the method demanded by the practical philosophy is the one that assures us of giving the greatest amount of transferable training.[3]

In order to fix in mind the differences among the three types of method just described, the following three samples of treatment are given. They are typical of the way in which the subject of light may be introduced in accordance with the three types of physical philosophy.

I. *Encyclopedic.*—A luminous body is one that emits light. A medium is any substance through which light passes. A transparent body is one that obstructs light so little that we can see objects through it. A translucent body is one that lets some light pass, but not enough to render objects visible through it. An opaque body is one that does not transmit light. A ray of light is a single line of light. A pencil or beam of light is a collection of rays, which may be parallel, diverging or converging; it may be traced in a dark room into which a sunbeam is admitted by the floating particles of dust which reflect the light to the eye.

The visual angle is the angle formed at the eye by rays coming from the extremities of an object. Knowing the distance of a body, we immediately estimate its size by the visual angle.

Laws of Light. (1) Light passes off from a luminous body equally in all directions. (2) Light travels through a uniform medium in straight lines. (3) The intensity of light decreases as the square of the distance increases.

II. *Abstract.*—Just as sound is defined as undulations in the air, or some other medium, that produce the sensation we call sound, so light, in the same sense, consists of undulations or waves in a medium that produce the sensation called light. Physicists have agreed to call this medium which transmits light the ether. It exists everywhere, even penetrating between the molecules and atoms of ordinary matter. Nothing is known about its nature and but little concerning the exact way in which light travels through it; but the masters of science generally agree that light is a wave motion in the ether, and that the vibrations of these waves are not longitudinal as in sound waves, but transverse. The transverse disturbances by means of which the waves are propagated are probably not transverse physical movements of the ether, but transverse alterations in its electrical and magnetic conditions.

A transparent body is one which allows light to pass through it with so little loss that objects can easily be distinguished through it. Examples of transparent bodies are glass, air, water. A body is translucent when it transmits light so imperfectly that objects can not be seen distinctly through it. Such bodies are horn, oiled paper, thin sheets of wood. Opaque bodies are those which transmit no light, as brick, pig iron, wooden boards. No sharp line of separation between these classes can be drawn; the classification is one of degree.

III. *Concrete.*—If a number of people

[3] For a more detailed discussion of this point, see Mann, "The Teaching of Physics for Purposes of General Education," Chap. VII.–X. New York, Macmillan, 1912.

are asked how large the moon looks, each will give a different answer. One may say that it looks as large as a dime, another that it seems as large as a saucer, while a third may say that it looks as large as a cart wheel. Then, too, the moon looks larger to every one when it is near the horizon than when it is high in the sky.

Infants reach for the moon and cry because they can not get it. Landsmen find it very difficult to estimate the distance between two boats at sea. On the other hand, when we look at a man climbing a distant hill, he appears as but a small speck on the landscape, yet we estimate his size correctly. We even use our knowledge of the man's size to estimate the distance or actual size of the hill or the height of the trees there. Ability to estimate distances and sizes from the way things look is obtained from long practise. Let us see if we can find the reasons for these things.

When sunlight streams through the window, it traces an outline of the window on the floor. If you hold your open hand so that the sunlight falls vertically upon it, the outline of the shadow cast on the floor resembles the outline of the hand. Most of us have amused ourselves making shadow pictures, by so placing the hands between a lamp and the wall that the shadow on the wall resembled a rabbit, a goose, a clown, or any other creature. We might draw the same outline by pivoting one end of a long straight pencil at the source of light, and moving it around the edges of the object, while the other end marked on a paper suitably placed. We can think of such a pencil as if it were the beam from a tiny searchlight moving about the edges of the object and tracing the outline.

When a sunbeam is allowed to enter a darkened room through a small opening, its path, as revealed by the dust particles in the air, is seen to be a straight line. Where it falls on some object it makes a bright spot. The sun, the opening, and the bright spot all lie on the same straight line; so from inside the darkened room we can determine the direction of the sun with reference to objects in the room, by means of the line drawn from the center of the bright spot through the center of the opening. Because light travels in straight lines, we judge the direction of an object by observing the direction in which light from the object travels.

Whatever you may think of the relative merits of the three types of method just outlined, it is clear that the only way to bring physics close to daily life is to bring daily life close to physics. The only method that assures the teacher of doing this successfully is that of the practical or concrete philosophy. It is possible that other methods may be more successful when the aim is to prepare students to meet past or present college entrance requirements, or to pursue later courses in some of the technical schools. Other methods can not, however, compete with the concrete method when the aim of the teaching is the union of education and life. Each teacher must, therefore, choose his own aim and adapt his methods to suit it. Let me in closing remind you of the importance of the choice. Had education and life been united long ago, the schools would not now stand discredited, nor would the demand for separate vocational schools have arisen. A union now of education and life will save the situation.

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ON THE APPEARANCE OF HELIUM AND NEON IN VACUUM TUBES[1]

At the last meeting of the Chemical Society, Sir William Ramsay, Prof. Collie,

[1] From *Nature*.